Dr. Bruce Kaiser XRF Analysis

In the heading "Caretaker" I have briefly explained why I was looking for the XRF analyses.

In my research, I became aware that a handheld XRF-devise was available from the Bruker Company; the latest version of that instrument was the Tracer III SD. Fortunately a Major University in the South-East did have that instrument. They informed me that if I brought Catherine Howard in Stained Glass to their laboratory, analysis could be performed with the Tracer III SD and so it happened.

A few days later I received the test results.

Not a chemist by profession, but still having some knowledge about the basics of the organic and inorganic chemistry, I do understand how XRF works. Also I have a basic understanding of the errors that can occur when the settings of the instrument are not properly met for a specific application. In short, analyzing scrap metal is quite different from analyzing stained glass.

Hence, when I started to examine the data from the University, I realized that comparing those numbers with the data from Dr. Robert H. Brill's "CHEMICAL ANALYSES of EARLY GLASSES" Volume 2 would be a monumental task considering the complexity of the glass compositions. To make it worse, I found an unexplainable discrepancy in the elemental data.

Feeling stuck, I searched for options at the Bruker website and became aware that the Tracers were developed by Dr. Bruce Kaiser. We have a saying in Holland: "If you don't shoot, you always miss". With that in mind, I contacted Dr. Bruce Kaiser by email and explained my "what, why and now what".

In regards with this adventure, it was the best thing I ever did. Dr. Bruce Kaiser answered promptly and very comprehensive but most educational as well. He debunked right away some of my misconceptions and included some "light" reading for better understanding of the principles of XRF. We exchanged a few more emails clarifying some more details, whereby Dr. Bruce Kaiser told me that Bruker does not have a loan/rent program for the Tracer III SD but in case I could take Catherine Howard in stained glass cross country, he would be happy to do the analysis in his lab. So again I travelled with Catherine Howard in stained glass but now to the West Coast to have it analyzed.

Meeting Dr. Bruce Kaiser in person was a real delight. After all, a lot of world famous people have the tendency to become distanced from the hoi polloi. Definitely not the case with Dr. Bruce Kaiser. Needless to say that we had a really good time.

A few days later I received his report. It became crystal clear that an intrinsic knowledge of glass is the key to the interpretation of XRF data. These are the net numbers of photons from each element in 60 seconds:

Vest Scan

Back and front

Net number of photons from each element in 60 seconds
Proportional to the elemental content. ***See plot in next chart***

net photons in 60 sec per element	Ag	As	Ba	Ba L1	Ca	Co	Cr	Cu	Fe	Ga	K	Mn	Ni	Pb L1	Rb	Sb	Si	Sn	Sr	Ti	Zn	Zr
back scan-0001	169	2495	144	357	1236	3436	1737	516	6693	418	395	46752	376	47025	269	758	202	214	1234	45	2217	937
back scan-0002	292	2642	255	301	1113	3505	1980	586	7475	317	315	44911	389	54216	168	896	181	324	1060	33	2239	750
back scan-0003	363	2664	183	302	1015	3363	2208	568	8095	532	302	43215	382	60686	433	802	176	293	1143	28	2358	811
back scan-0004	303	3467	246	410	920	3301	2177	655	8076	550	235	42384	347	63530	257	732	110	115	1123	29	2414	885
back scan-0005	305	3365	313	301	858	3371	2336	1653	9578	763	202	41464	405	71403	278	519	199	83	1175	60	3066	835
back scan-0006	514	3920	262	271	961	3223	2434	3133	11133	554	161	42036	339	72702	306	760	132	216	1187	45	4028	911
back scan-0007	468	3842	224	377	773	3249	2349	3055	10905	584	175	41341	359	73152	324	624	134	108	1189	7	3902	724
back scan-0008	230	3739	347	306	809	3192	2509	2927	10609	605	192	42362	362	73720	431	625	180	226	1086	40	3857	839
back scan-0009	352	3952	257	301	834	3340	2470	3404	11172	572	167	42046	365	75326	441	599	107	121	1173	89	3877	958
back scan-0010	277	4221	293	368	759	3168	2786	3892	12137	631	242	40685	305	81604	227	762	133	164	1200	60	4375	925
back scan-0011	473	4453	356	310	648	3054	2983	5763	14053	704	97	39220	282	86774	283	865	161	286	1283	82	5344	822
back scan-0012	388	4844	210	357	552	3037	2972	6909	15108	711	78	38624	314	90135	435	544	112	227	1314	68	6184	852
back scan-0013	506	4830	148	397	532	2814	3387	7442	16051	835	198	36090	340	98888	389	653	153	151	1191	1	6628	961
back scan-0014	101	5403	354	394	497	2693	3437	7311	16201	902	62	33933	252	104490	325	733	135	176	1214	8	6758	1021
back scan-0015	272	5997	190	320	391	2602	3688	7888	17174	1006	107	31916	218	112469	427	514	151	206	1323	1	7112	1041
back scan-0016	239	6227	282	333	340	2441	4166	8708	18015	1013	64	28873	288	120286	389	779	119	319	1259	42	7359	808
back scan-0017	195	6754	203	410	310	2312	4440	8292	18449	1082	73	26163	202	129870	307	646	139	197	1335	1	7266	840
back scan-0018	332	7977	189	353	265	2120	4906	8184	18899	1210	46	24824	266	138579	587	588	99	230	1290	1	7054	792

net photons in 60 sec per element	Ag	As	Ba	Ba L1	Ca	Co	Cr	Cu	Fe	Ga	K	Mn	Ni	Pb L1	Rb	Sb	Si	Sn	Sr	Ti	Zn	Zr
vest scana-0001	427	970	-1	29	2308	43	14	282	917	8	506	97	7	7125	184	789	180	228	388	31	5466	742
vest scana-0002	455	1022	159	32	2206	12	45	304	880	0	516	61	25	7039	451	764	242	102	545	29	5482	930
vest scana-0003	419	1215	156	4	2050	23	22	261	870	0	497	87	49	6777	296	728	230	73	407	81	5502	790
vest scana-0004	433	1232	135	44	2111	29	33	256	946	-2	507	80	21	6705	378	748	201	163	488	30	5361	733
vest scana-0005	444	1204	223	15	2134	43	9	287	914	-1	514	61	35	6837	227	817	206	67	484	68	5506	876
vest scana-0006	364	1127	123	29	2124	4	7	277	881	0	528	54	3	6816	366	721	199	107	486	57	5499	994
vest scana-0007	310	1085	156	51	2037	35	29	294	796	19	476	88	22	6696	279	791	146	297	440	24	5427	878
vest scana-0008	409	954	256	66	1974	12	20	290	896	13	508	85	8	6822	296	751	187	174	391	5	5264	847
vest scana-0009	224	1243	135	109	2138	9	22	302	953	36	495	50	31	6693	273	824	175	171	404	22	5396	911
vest scana-0010	291	1176	180	31	2083	-20	45	234	862	36	540	64	9	6488	285	790	153	163	469	73	5355	830

Dr. Bruce Kaiser was well aware that representation of data in this format is impossible to understand for most. Therefore he used bar graphs to make it easier for us, common folks. In the next pages he gives an overview of the glasses as they were used through the centuries. With bar graphs he shows how much of the elements like Arsenic (As), Chromium(Cr), Manganese(Mn), Copper(Cu), iron(Fe), Lead(Pb), and Zinc(Zn) are present in the various pieces of glass.

He then describes how the blue background has a high concentration of Copper on front and back, indicating that the glass is true blue glass and not stained blue. After that he gives a brief explanation as to the use of Silver Stain for the color yellow. His graph shows a high concentration of Silver(Ag) on the medallion.

Dr. Bruce Kaiser comes to the most important aspect of the analysis.

Composition, manufacture and distribution

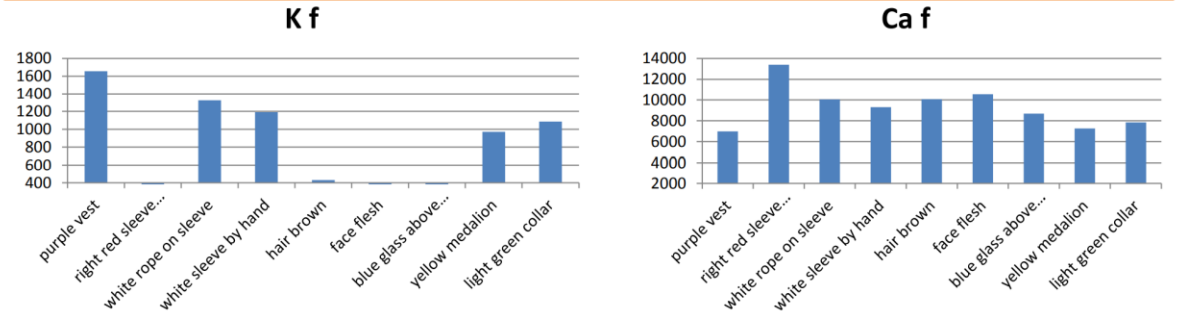
Prior to c.1000, most coloured glass was of a soda-lime-silica composition. In Northern Europe soda glass was eventually almost totally superseded by potash-lime-silica glass (Forest glass). Forest glass continued to be used in stained glass for the duration of the medieval period until soda glass again began to be used in the 16th century.

The potash (K_2O) found in Forest Glass was derived from wood ash. In *De Divers Artibus*, Theophilus describes the use of beech wood as the preferred source of ash. Other plant matter, such as bracken, was also used.[13] As well as containing potash, beech ash comprises an assortment of compounds including iron and manganese oxides, which are particularly important for generating colour in glass.

Medieval stained glass panels could be created either by the cylinder blown sheet or crown glass (window) method.

Forest glass was manufactured in Burgundy and Lorraine near the Rhein; in Flanders; and in Normandy, in the Seine and Loire Valleys. It was distributed throughout mainland north-west Europe and Britain in the form of ready-made sheets. The application of painted decoration to and final shaping of the sheets was carried out at glass working centres close by the final destination of the glass.

Note that K appears in 5 of the glasses. This is known as Forest Glass, but 4 of the glasses show no K indicating that this glass likely Na glass



After his explanation of differences between Forest glass and Soda lime glass, this image shows on the left side that some of the glass contains Potassium (K) "Kalium" while it's absent in other pieces. It is undisputable that both kinds of glass were only used in the transition period during the first part of the 16th. century.

His conclusions draw some interesting facts. Indeed there is only one known stained glass artwork attributed to Hans Holbein Jr. at the Getty Museum as:

"A Premonstratensian Canon"
https://www.getty.edu/art/collection/objects/220332/possibly-after-hans-holbein-the-younger-a-premonstratensian-canon-swiss-about-1520/

Moreover, only a few stained glass artworks from his father, Hans Holbein Sr, are known and they are among the most extremely beautiful stained glass windows ever made.